

portion of the sonorous wave in compression from that in extension, the result is that we have a variation in the resistance of the line. Now this variation in resistance depends upon the compression and dilatation of the molecules. They depend upon the tone of the voice, and the result is the resistance of the current varies with its variation of pressure, and at the distant end we have currents varying exactly as the voice varies, and reproducing on the telephone all the effects which we have seen. Hence follows the action of the microphone, and the action of the transmitter is one which depends upon the variation produced in bodies by the sonorous vibrations of the voice. As I am now speaking at that telephone, all the molecules of that transmitter are thrown into this elaborate series of compressions and dilatations. The current is varied; it goes to the room below, and is reproduced upon the telephone, as we have heard. Hence the effect is due to the difference of pressure, as is proved by using atmospheric pressure, and applying heat; and any large increase of pressure results in sound being reproduced.

No one has ever been nearer a great discovery than Mr. Edison. His telephone is based on the variation of resistance due to pressure. He used carbon and finely divided matter, but he worked on the idea that the difference in pressure was produced by the vibrations of a diaphragm. Had he thrown away his diaphragm he would have forestalled Prof. Hughes in this respect, and found that the sonorous vibrations themselves produced this difference of pressure. The great secret of Prof. Hughes's discovery is that sonorous vibrations and electrical waves are to a certain extent synonymous.

Now as to the uses to which this instrument is capable of being applied. It has been applied to surgical purposes in the form of the stethoscope. Though it does not show very markedly the beats of the heart, because they are more mechanical thumps than sonorous vibrations, yet it will show the injection and ejection of air in the lungs, and for many other surgical purposes it must become a valuable instrument. It admits us to some of the mysteries of insect life, and by its means we can hear sounds emitted by insects which have never been heard before. Going further it has enabled the deaf to hear; deaf persons who never heard a telephone before have been able to hear distinctly. It has enabled us to hear the physical operation which goes on in the process of crystallization of bodies and other things which before were wholly inaudible; and in fact it is impossible to say to what uses it may not be put.

It is rather remarkable that in an excellent paper read before the American Electrical Society, the author, Mr. Pope, makes these curious remarks:—

"The most striking results are to be looked for in the direction first pointed out by Mr. Gray, for the reason that if an effectual method of controlling the resistance of the circuit by means of atmospheric vibrations can be discovered, the source of power, which in this case is the battery, may be augmented to any required extent. It is not to be denied that the problem thus presented is one of exceeding mechanical difficulty, but there is no reason to suppose that it may not be successfully solved. It is to the development of this variety of the speaking telephone rather than to that of the magneto instrument that inventors will find it most advantageous to turn their attention, for I hazard little in saying that the latter has already reached such a surprising degree of efficiency, as to leave comparatively little more to be done within the necessary limitations which have been pointed out."

Mr. Pope throws out what has been done with the exception of the supposed mechanical difficulty, and that has been got over by a halfpenny money-box.

Now one very pleasing and gratifying circumstance attaches to this discovery of Prof. Hughes: he has thrown it open to the world, and by that means he has no doubt checked that species of immorality—I don't know what else to call it—connected with the infringement of the patent law, as regards the telephone. He allows us all to manufacture microphones for ourselves, but even he has been subjected to rather a peculiar incident. One impulsive and active gentleman who was present at the Royal Society the other night when Prof. Hughes first described his invention, went home and made himself a microphone, wrote a description of it and sent it off post-haste to Paris. A short time afterwards Prof. Hughes himself with great care prepared a paper to be read before the French Academy, but to his great surprise he found that he had been

forestalled, a description of his instrument had already appeared in the Paris prints from the gentleman in question.

There are lessons to be learnt from this discovery, and the principal lesson is—we can all of us with the means at our disposal cross-question nature and find out her secrets, and there are many secrets which yet remain to be divulged. We learn the wonderful connection which exists between all the physical forces: heat, and light, and electricity, and magnetism, are all co-related, and it has come to this, that what boys have said in joke has come to pass in earnest. We have been able to convert electricity into light, and light into electricity. We are now able to convert electricity into sound, and sound into electricity, and thus we are enabled to see the thunder and to hear the lightning.

### THE SCIENTIFIC AIMS AND ACHIEVEMENTS OF CHEMISTRY<sup>1</sup>

MORE than a generation has passed away since my predecessor in the chair of Chemistry, Prof. Bischof, who was so full of merit in the domain of chemical geology, held the high office which the friendly confidence of my colleagues has entrusted to me for the ensuing university year. Since that time chemistry has undergone important changes, and its position upon the German high schools has also become an essentially different one.

At that time a general discouragement had taken root amongst the most eminent chemists. It was believed that all speculation had to be dismissed from the field of chemistry, and particularly that all atomistic considerations had to be discontinued, because whole categories of facts could not be made to agree either amongst each other, nor with the general theoretical views of that time.

At our high schools at that time chemistry was only taught from the chair; very often by teachers who were essentially appointed for other subjects. At most of the universities the students could be admitted to practical work only by favour of the teachers, and even Liebig's laboratory at Giessen, the first of all educational laboratories, only just then received its interior arrangement.

How different now! Well aware of its task and its aims, scientific chemistry, in close connection with physics, advances slowly, it is true, but with self-reliance and a certain confidence.

Each university has its special chair of chemistry, many indeed have several. Richly furnished laboratories, and very often luxurious edifices, are at the disposal of chemical students in nearly all German universities, and the chemical lectures are the best frequented ones almost everywhere.

All this and also the circumstance that it is just a chemist who is able to day, as a representative of the entire university, to speak to the entire university from this place, proves, doubtless, that our science is now generally recognised to the extent it merits. But as on many sides it is over-estimated, it is yet more frequent, on the other hand, that its scientific right of existence is doubted. While outsiders who may occasionally have seen a chemical experiment, or may have heard of the grand applications of chemistry to practice, declare chemistry to be the finest science of all, although they may not be able to form an idea concerning its scientific aims, other one-sided representatives of so-called humanistic studies, who also mix up the applications of chemistry with its scientific task, tend towards the unjustifiable view that chemistry ought really to be taught only at polytechnic schools, but not at the "universitas litterarum."

The propagation of such erroneous conceptions renders it the duty of the chemist to appear as the defender of the science he represents, and it will doubtless be considered fully justified if to-day I try to explain to you the scientific position of chemistry and its participation in the great progress of universal science.

Chemistry has often been designated as the sister of physics, and both subjects are in reality so nearly related, their domains are so contiguous, that the layman cannot understand the difference, and that even the scientific man can hardly fix the limits.

Chemistry and physics together form that group which may be designated as *general natural science*, inasmuch as the occurrence of their materials of study is unessential, and the laws recognised by them are valid everywhere: Astronomy, geography, geology, botany, and zoology (the latter including those more special subjects treating of man, and which form the scientific part of medicine), all these, which ought to be comprised under the

<sup>1</sup> Address delivered on assuming the Rectorate of the Rhenish Friedrich-Wilhelms-University of Bonn, October 18, 1877, by Prof. Aug. Kekulé.

name of *special natural science*, are tied to certain circles of objects of study, and the truths they have established are valid only for these circles. Even that generalisation of the so-called organic natural sciences, which is designated as biology, cannot very well be called a general natural science, because if indeed anywhere else than upon the earth there exists something similar to what we call life here, there is yet but little probability that the laws of terrestrial life may be applied to that life of other worlds.

The common task of *general natural science*—of physics and chemistry, therefore—is the investigation of matter, of its properties, its changes, and of the laws of these changes; and the laws recognised by them must be applicable wherever there is matter at all.

Now with regard to the *difference* between *physics* and *chemistry*, it strikes the superficial observer that modern physics treats, in a more general manner, of the properties and changes of properties of bodies, and in doing so that it contemplates the separate bodies only as the bearers of the properties; while chemistry studies the separate bodies differing with regard to their material, and that it touches their properties only inasmuch as they appear necessary for distinguishing the bodies. One might be inclined to found a definition of the two disciplines upon these differences. But when we enter more deeply into the subject we shall see that the essential differences must be looked for elsewhere.

Of all conceptions which the human mind could form regarding the essence of matter, only the hypothesis of *discrete* mass-particles, the atomistic hypothesis therefore, has led to an intelligible explanation of facts. Even if nobody who has followed the scientific discussions of the latest time, can deny that the tendency of natural scientific reflection just now again lies in the direction of reducing the differences of materials to dynamic causes, yet we must certainly own that *at present* the observed facts can be deduced as necessary consequences from the atomistic theory only. On this point physicists and chemists are no doubt agreed. And if even modern representatives of speculative philosophy concur in the view that all natural knowledge leads to the mechanics of atoms in the last instance, then we may doubtless use the atomistic theory *preliminarily* as the basis of further reflections in the domain of natural science and, *for the present at least*, found upon it the definition of the separate branches of natural science, be it only in order to render a clearer account to ourselves of their tenour and of the limits of their domains. Now the sum total of all knowledge obtained with regard to matter has led to the following *maxims of the atomistic theory*.

We must imagine that matter consists of small particles, uniform in their material and not further divisible, not even by chemical processes,—of *atoms*. These atoms accumulate in consequence of forces inherent in them or acting upon them, and thus produce systems of atoms, or *molecules*. In the gaseous state these molecules move about in space as isolated beings, in the other aggregate states an attraction of molecules also becomes apparent, and thus the *masses* originate which are able to act upon our senses directly.

If this conception of the essence of matter is taken as a basis then we may define chemistry as the *science of atoms*, and physics as the *science of molecules*, and it lies near then to look upon that part of modern physics which treats of *masses* as a separate discipline, and to reserve for it the name of *mechanics*. Thus mechanics appears as the fundamental science of physics and chemistry, inasmuch as both are obliged to treat their *molecules* or atoms respectively as masses in certain considerations, and particularly in calculations. Mechanics, physics, and chemistry, however, are the bases of all special natural sciences, because it is evident that all changes, no matter whether they occur, in the great cosmos, or in the microcosmos of the vegetable or animal body, can but be of a mechanical, physical, or chemical nature.

Now from the fact that chemistry has to do with the study of atoms, of the building stones, therefore, of which the molecules are constructed which physics treats as a whole, it results directly that the theoretical investigations of chemistry offer more difficulties than those of physics, and that theoretical chemistry can progress in certain directions only after theoretical-physical knowledge has sufficiently advanced. The comparatively low state of theoretical chemistry thus seems not only pardonable but natural, and it becomes clear why for the present theoretical-chemical investigation has principally turned its attention to those questions which are more or less independent of physics. Thus we understand why *chemical dynamics* is as yet an almost uncultivated

field upon which the materials, which are heaped up in immense profusion could, up to the present, not find a theoretical treatment, while on the domain of *chemical statics* ripe, or at least partly-developed fruits, were reaped in plentiful quantity.

It will not be difficult to show that chemistry and chemists have, in this direction, materially contributed towards the progress of the general doctrine of atoms, therefore towards the progress of our knowledge of the nature of matter.

Since the (as far as we know) first foundations of the scientific observation of nature were laid by Democritus, the most elementary maxims of the theory of matter have remained the same. "From nothing nothing can come; nothing that is can be annihilated; all change is only combination or separation of particles." But the atomistic theory of antiquity was more a precursor of the views which we now designate in physics as the molecular theory; it contained, even in its further development, no fundamental thought of a specially chemical theory.

The first fundamental maxim of scientific chemistry was pronounced towards the end of the seventeenth century by the chemist Boyle, who was first to define the conception of the *chemical element* as that which is not further divisible into materially different parts. It will not matter whether many or perhaps all the bodies which we now consider to be chemical elements may be found to be further divisible in the progress of knowledge—although there is at present no real indication for this—the idea of the chemical element will always remain unaltered.

With this idea of the chemical element that old conception of the indestructibility of matter was then connected, and thus the further fundamental maxim of chemistry originated, of the invariability of elements, which has not further been questioned since Lavoisier's celebrated experiments on the often-pretended change of water into earth, and which finds its confirmation in all chemical facts.

From these views the *chemical atomistic theory* arose at the beginning of the nineteenth century, and the English chemist Dalton is with right regarded as its founder. While, after Democritus, the difference of all things is caused by the difference of their atoms in number, size, shape, and order, a *qualitative* difference of atoms, however, does not exist, Dalton first in a definite manner supposed the existence of *qualitatively different* elementary atoms. He was first to ascribe to these qualitatively different atoms *certain weights* which are characteristic for the various elements; he first showed that these relative *atomic weights* may be determined by chemical study.

As the conception of the chemical element so will also the conception of the chemical atom, as that quantity of elementary matter which is not further divisible by chemical processes, remain for ever. For chemistry, the question whether the chemical atoms are originally units (*einheitliche*) and absolutely indivisible beings, is of no importance. Let the proof be given that the chemical atoms are formed of particles of a finer order, or let the theory of revolving rings founded by Thomson, or some other similar conception which understands atoms to result from continuous matter, be proved in the progress of knowledge, the conception of chemical atoms will not be altered or annihilated. The chemist will always welcome an explanation of his units, because chemistry requires atoms only as a starting point, not as an end.

Dalton's atomistic theory from the very first suffered from a certain imperfection which consisted in its speaking of the atoms of compound bodies as well as of those of elementary ones and thus did not distinguish the ideas of atom and molecule. For the first period, during which the foundations of chemical science had to be completed, no essential harm arose from this want of clearness, but later on, when the structure was to be developed further, it caused considerable confusion.

It is true that already in 1811 Amadeo Avogadro pronounced the maxim that gaseous bodies contain an equal number of molecules in equal spaces, and that even the molecules of elementary substances consist of several atoms, and that in 1814 the French physicist Ampère arrived at the same conclusions; but this idea, which was so fertile in the future, hardly attracted any notice at first. In its application it led to contradictions which seemed insolvable at that time, and it was therefore abandoned, although the great chemist Dumas had taken it for some time as the base of his considerations. More than that, it was forgotten until forty years later the Italian chemist Cannizzaro recalled to the memory of his colleagues the merits of his countryman.

In the meantime chemists first, and later on physicists as well,

had arrived at precisely the same conceptions, starting from new and perfectly independent points of view.

The chemists, with Laurent and Gerhardt as leaders, were led by purely chemical considerations and essentially by reasons connected with systematics, to distinguish clearly between the ideas of atom and molecule, and to find methods which, in the perfection at which they have now arrived, render possible the determination of the relative weights of the atoms and molecules, and even of the absolute number of atoms in the molecules, for all more perfectly examined substances, by the discussion of purely chemical facts. Amongst others they arrived at the result that the molecule even of elements consists of two atoms as a rule.

In physics, however, the mechanical heat theory caused a probability bordering upon certainty to be ascribed to the fundamental thought of Avogadro's hypothesis; and when our celebrated colleague, Clausius, in the course of his classical investigations, had arrived at the conception that even in elements the molecules consisted of several atoms, then he could express his satisfaction regarding the fact that chemists before him, on totally different ways, had already arrived at the same results.

After, in this manner, Avogadro's hypothesis on the nature of gases had obtained general recognition, and the relative weights of the gas particles could thus be deduced from the specific gravities of gases; after, on the other hand, we had learned to determine the relative weights of the chemical molecules by chemical considerations, then it appeared that both values were identical, and thus we arrived at the conception, which anyhow was probable on account of its simplicity, but which was not a necessary one previously, that the gas particles and the chemical molecules are identical, that heat therefore, is able to subdivide matter down to the chemical molecules.

The chemical part of the atomic theory was essentially extended some twenty years ago by that hypothesis, made by chemists, which has been designated as the theory of the chemical quantivalence of atoms. In its fundamental thought this hypothesis only says that besides the characteristic atomic weight which is the cause that the elements combine in certain proportions of weight, the atoms still possess a further fundamental property, which causes them to combine exactly in those numbers in which they do. As we could not, at first, arrive at a clear conception of this fundamental property, we simply ascribed a certain number of chemical attraction units to the materially different atoms, and accordingly called them uni-, bi-, tri-, or quadrivalent.

Now this hypothesis of the chemical quantivalence of elementary atoms of course still offers many dark points, but yet it has led to the recognition of a law which, not only for chemistry, but for the entire atomic theory is of fundamental importance, and which chemists call the law of the connection of atoms (*Verketzung der Atome*). The separate atoms of a molecule are not connected all with all, or all with one, but, on the contrary, each one is connected only with one or with a few neighbouring atoms, just as in a chain link is connected with link.

At the same time it is evident that the atoms within the molecules must be in constant motion, and if, indeed, nothing certain is known respecting the nature of this motion, yet it results from this very law of the connection that the intramolecular atomic motion must be of such a nature that the separate atoms move about certain positions of equilibrium without ever leaving them, as long as chemically the molecules continue to exist. The motion of atoms, therefore, is certainly similar to that of the molecules in the solid state, and thus it may be said that the molecules of existing substances are solid aggregations of atoms. A state of motion similar to that which the molecules of liquid bodies possess, occurs only with chemical changes, by which molecules of different atomic structure are formed, and then evidently only in a transitory manner and only for single atoms. A state of this kind doubtless plays an important part not only in fermentation phenomena, but also in the chemical processes occurring in living organisms. The nature of the motion of atoms is, as I said before, unknown at present. Perhaps it may be imagined as an oscillatory one in such a way that the number of oscillations executed in the unit of time exactly represents the chemical value, and that atoms engaged in functional oscillation, and perhaps striking against each other, appear in chemical combination. Then the chemical quantivalence of atoms would have to be considered as a constant one with even greater probability than hitherto. Anyhow one might imagine that polyvalent atoms, at temperatures which, for the substances in question, might be called ultra-hot, do not meet with another atom during one or even more oscillation phases, while adding a part of their

motion-energy to the molecular motion; a conception which would correspond to the present conception of unsaturated affinities. We would have to think it probable, further, that upon raising the temperature still more, this intermediary state of partial dissociation would be followed by one of total dissociation, during which isolated atoms move in space, just as has already been proved for mercury vapour at temperatures of easy access.

The law of the connection of atoms based upon the hypothesis of chemical quantivalence, at present accounts only for the chemical serial connection (*Aneinanderreihung*) of atoms, without explaining their position in space and the form of molecules caused by it. But even now, from investigations on molecular volumes it results that the nature of the connection of atoms influences the mean distances of atoms.

The circumstance that with isomeric substances the boiling-point of that modification is the highest for which the law of the connection of atoms supposes a chain running in a straight line, while volatility increases the more ramifications the chain shows, the more compressed, therefore, the molecule appears from a chemical point of view; together with the maxim, probable in itself, that the position of the point of gravity and the moment of inertia of the rotating molecule must be of influence upon volatility, seem to indicate that the views on the chemical connection of atoms at the same time give us some notion on their mean position in space. The calculations made by Emil Meyer, of the molecular diameters, molecular transverse sections, and molecular volumes, also seem to support this view. Thus the probability of the hypothesis pronounced by Le Bel, and worked out further by Van't Hoff, of the unsymmetrical carbon, according to which the four affinity bonds of the carbon atoms, which had already been represented tetrahedrally, are imagined to exist in space in a tetrahedral position, is increased. An hypothesis which may perhaps not merit the unconditional praise which Wislicenus has bestowed upon it, but which certainly much less deserves the bitter derision which Kolbe was inclined to throw upon it.

The hypothesis of chemical quantivalence further leads to the supposition that also a considerably large number of single molecules may, through polyvalent atoms, combine to net-like, and if we like to say so, sponge-like masses, in order thus to produce those molecular masses which resist diffusion, and which, according to Graham's proposition, are called colloidal ones. The same hypothesis in the most natural manner leads to the view, already pronounced by our genial colleague, Pflüger, that such an accumulation of molecules may go further yet, and may thus form the elements of the form of living organisms. Of these mass-molecules we may perhaps suppose further that they, through the constant change of position of polyvalent atoms, show a constant change in the connected single molecules, so that the whole—and of course under generation of electricity—is in a sort of living state, particularly since, through the same change of position, adjacent molecules are drawn into the circle of combination and newly-formed ones are expelled. To follow such speculations any further at present would, however, be equivalent to leaving the basis of facts rather too far behind us.

Really fertile hypotheses on the nature of that force, which brings about the combination of atoms, have not been made up to the present. The electro-chemical theory, so ingeniously worked out by the great Berzelius, of which, during whole decades, it was believed that it would lead to a satisfactory explanation of chemical facts and to their combination with physical phenomena has proved completely insufficient. In all probability in a future period of the development of science it will again be taken up, and will then, in a modernised form, bear its fruits.

In any case besides the chemical quantivalence, which decides the number of combining atoms, the specific intensity with which this combination takes place, must also be considered. Here we must suppose that the atoms combined in a molecule, and therefore saturated with regard to their quantivalence, do not only exercise an attraction upon each other but also upon the atoms of neighbouring molecules, and that thus a molecular attraction results, which is caused by the attraction of the separate atoms and therefore depends on their quality. Only in this way we can explain the process of chemical decomposition and the existence of that infinite number of more complicated things which are supposed to be molecular additions or molecules of a higher order. Unquestionably the same cause plays a part in so-called mass-effects and in catalytic decompositions. The formation of solutions must also be ascribed to it, which hitherto were considered as chemical combinations in varying proportions, but

which are now more appropriately called *molecular mixtures*. The same fundamental cause further gives rise to the phenomena of cohesion, adhesion, and capillary attraction, and it seems therefore as if the supposition of special molecular forces is in no way necessary any longer.

Now as the attraction of atoms depends on their *quality*, it is also clear that the molecular attraction caused by such atomic attraction must, under favourable conditions, produce an *orientation* of all molecules combining with one another, and must thus lead to bodies of a regular molecular structure, therefore to *crystals*.

Lastly, the question whether the properties of atoms are dependent on their *weight* has much occupied the chemists of modern times. Positive results which could be rendered clear in a few words have not yet been obtained, but it seems, according to the observations made by Lothar Meyer and Mendelejeff, as if not only the *chemical* properties and specially the chemical quantivalence of atoms and the intensity of their mutual combination, but also the *physical* properties, which at present are still treated as *constants* for materially different objects, were a function and indeed a *periodic function* of the atomic weight. The mathematical form of this function is no doubt of a peculiar nature, but one thing seems certain, viz., *that the numerical value of the atomic weight is the variable by which the substantial nature and all properties dependent on this are determined*.

Thus there again seems hope that it will be possible to reduce all properties of matter, including gravity, to one and the same force.

The right of introducing all such speculations into the domain of exact science, has been questioned very much. It is generally conceded, indeed, that the setting-up of hypotheses on the domain accessible to exact investigation, as a method of investigation, is useful, inasmuch as it often may accelerate the progress of exact knowledge. But it is at the same time often believed that speculations beyond a certain limit are not admissible. The scientific value of all atomistic considerations particularly has ever, and also in the most recent time, been very much doubted. It has been pretended specially that the supposition of atoms did not explain any properties of bodies which had not first been ascribed to the atoms themselves.

We must own that such remarks contain many truths, but just for that reason it seems necessary that we examine the limit of their correctness.

It is generally acknowledged that the results of exact observation have the value of facts, therefore possess that degree of certainty which human knowledge can attain at all. It is further not contested that to all those laws which, independent of hypotheses on the nature of matter, are deduced from facts, nearly the same certainty must be ascribed as to facts themselves. It is just as incontestable, however, that the human mind in the positive understanding of facts does not find complete satisfaction, and that therefore natural sciences have to follow a yet further and higher aim, *that of the knowledge of the essence of matter and of the original connection of all phenomena*.

But the essence of matter is not accessible to any direct investigation. We can only draw conclusions regarding it from the phenomena which are accessible to our observation. And thus it is evident that there is a certain limit which, moreover, is influenced by the state of our knowledge at any given time, beyond which positive investigation loses ground and where the path is only open for speculation.

If, therefore, the single investigator, following the inclinations of his nature, rests satisfied with positive investigations and renounces all speculations, it is yet clear that to science as such this is not permitted.

By way of hypothesis, based upon what is known as facts, ideas must be formed on the nature of matter; the consequences of these ideas must be developed logically, and, if necessary, by the aid of calculation, and the results of these theories must be compared with the phenomena accessible to observation.

Of course, the *complete* truth will never be reached in this way, or there will, at least, never exist complete certainty that our conceptions are really identical with truth. But that conception which is simplest in itself, and which in the simplest manner accounts for the greatest number of phenomena, and finally for all, will have to be considered not only as the best and most probable one, but we shall have to designate it as relatively, and we may say, *humanly*, true.

By this the scientific right of existence of speculative investigation is no doubt proved, also for the so-called exact sciences, because beyond a certain limit these indeed cease to be exact.

Simultaneously, however, the scientific value of the present atomic theory is also proved, because it has not been contested that, even in its present and still extremely incomplete form, it accounts satisfactorily for an uncommonly large number of facts, better than any other conception.

It will certainly require further extension, and also a deeper fundamental structure; but at present there is very little probability that it will be completely superseded by essentially different conceptions.

There are other reproaches which have been made to chemistry specially, and still more to chemists, now and since the time of Lord Bacon; and even chemists cannot deny that they were not altogether undeserved.

It has been said that chemistry wilfully makes innumerable single hypotheses which are neither in connection with one another nor with the whole; that the value of hypotheses is over-rated by her disciples, far too great certainty being ascribed even to such as are only little justifiable, and that they are treated as if they had been actually proved; and finally, that her hypotheses are always gradually raised to articles of faith, and that everybody who sins against such dogmas is prosecuted as a heretic.

Recent times have also, in this direction, brought about a considerable improvement. The justification and the value of hypotheses are now recognised in chemistry, but at the same time the true value of hypotheses is also understood by chemists.

In chemistry also, as in all domains of science, blind faith in authorities has been crushed, and by this alone the danger of dogmatising is lessened. And should perhaps any one, who holds antiquated views, try to attach his dogma upon progressing science as a restraint, he will always find the striving young generation, the representatives of the future, ready to remove unjustified impediments. If others, in the fiery zeal of youth, should be inclined to look upon daring flights of fancy as scientific hypotheses and to give them out as such, then those who are more moderate by themselves or by the riper experience of age, will always feel it a duty to step in as regulators.

The school of independent, and at the same time quiet thinkers, is now so numerous represented also among chemists, that a constant development of the science may be confidently expected, and an overgrowth of weeds need no longer be feared. Also in chemistry we are now well aware of the continuity of human mental work; the present generation no longer looks with despising contempt upon the work of their predecessors; far from thinking themselves infallible, they know that at any time it remains to the future to continue the work of preceding generations.

## ON THE CAUSES OF THE ASCENT OF SAP IN TREES<sup>1</sup>

THE question as to what forces cause water to rise to such a remarkable height (frequently) in trees has had very various answers given to it. But these have mostly failed to account adequately for the phenomenon.

Capillary action is perhaps the oldest cause adduced. The view was long popular that water rose in trees like oil in a wick, the connected vessels of the wood forming capillary tubes. This view lost force when it was known that the wood of coniferæ was without vessels; and it did not explain the weakening or stoppage of the rise of sap produced by amputation of the roots, nor the presence of air in the columns of sap.

Shortly after Dutrochet's thorough study of diffusion, this phenomenon was called in to account for the rise of sap. One grave objection to such a theory is the rapidity of the ascent of sap (it has been carefully measured) as compared with the slowness of diffusion, which depends simply on molecular motion; another is the inevitable consumption of the osmotic force of tension. So that other problematical forces had to be called in.

When Jamin found that the imbibition of water through fine porous substances (*e.g.* blocks of gypsum) took place with great force, and that the air could thus be compressed to several atmospheres, an effect of this nature was affirmed to occur in living plants, the cell membrane being considered a porous substance. But in fact the natural saturated cell membrane has no air-filled pores, but only pores already filled with water, and even the hollow spaces, bounded by the cell membrane, are partly filled with water; besides, the fact that a branch, immediately after being cut off, loses in great measure the power of raising water, is against this theory.

<sup>1</sup> Abstract of a recent paper in *Der Naturforscher*.